4th ARIES Annual Meeting

Status of W10.1 (TA) Material Testing CERN-HiRadMat

Status of W10.2 (TA) Material Testing at GSI M-Branch

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21 April 2021

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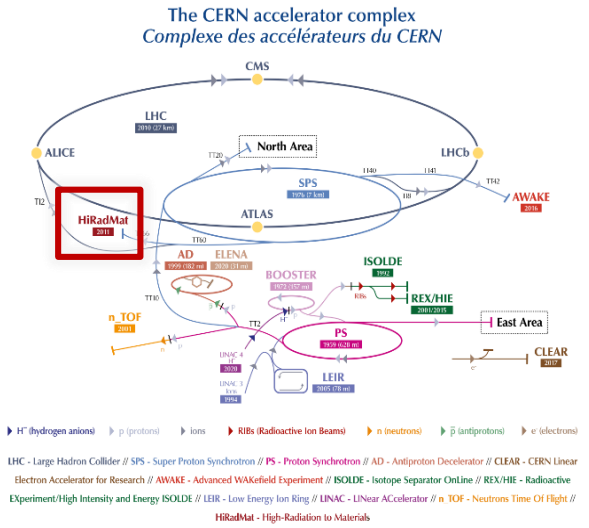
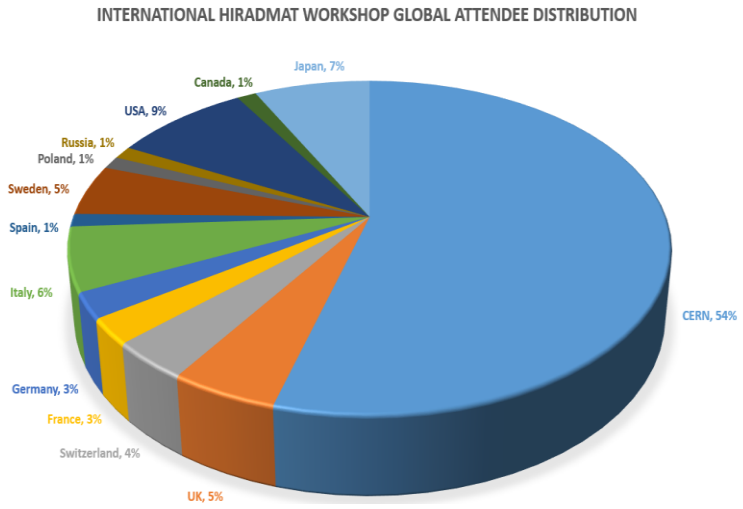
A “flash” reminder of HiRadMat

- HiRadMat (High-Radiation to Materials) is a user facility for high-energy, high-intensity pulsed beams.
  - The facility was comissioned in 2011 and located in SPS Point 7.
  - ~**35** succeseful experiments since the comissioning with the support of Eucard/Eucard2/ARIES



Since Dec. 2018 – LS2 (1)

- A very succesful, ARIES supported workshop organized to re-focus the community interested for HiRadMat experiments in 2019 :



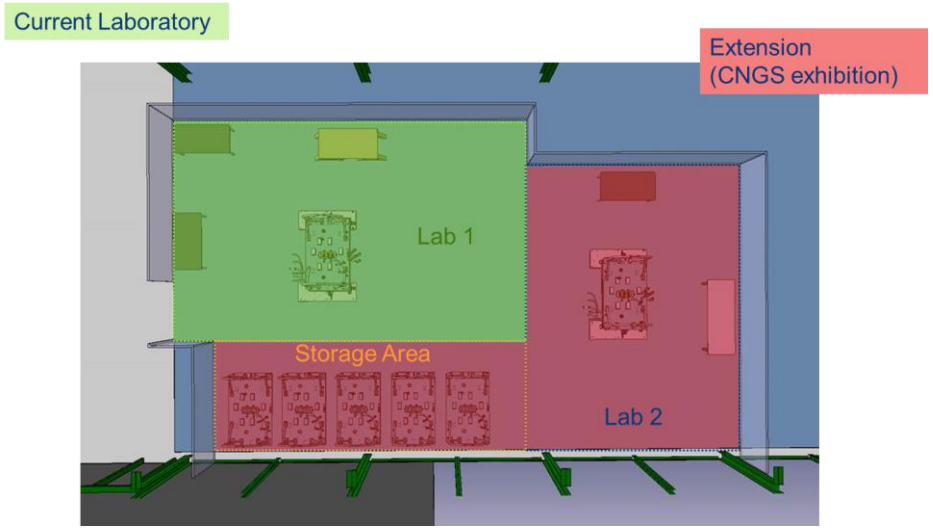
37 presentations from 12 different topic areas (i.e. Remote Sensing & Beam Instrumentation; Materials Science & Beam Induced Damage Research …)

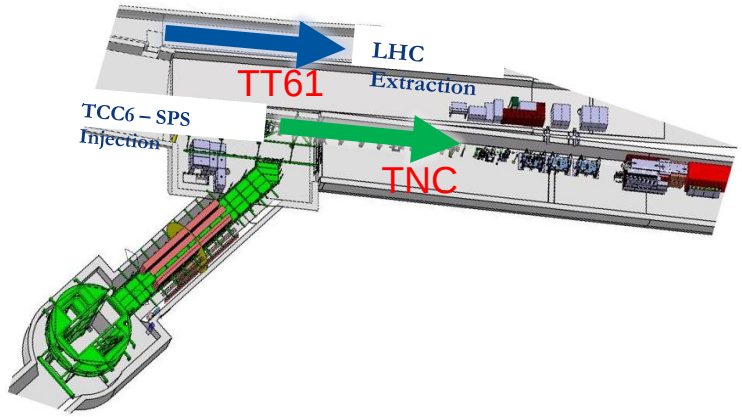
~8 Letters of Interest for future experiments (R&D and one physics proposal from Univ. Oxford)

Since Dec. 2018 – LS2 (2)

During 2019 – 2020 : Facility upgrades and consolidation.

- **Surface lab extension ongoing** – planned for completion by August 2021.
- **A full survey and alignment of the HiRadMat (TT66) line** completed.
- **New patchpanel @ TT61**, it will facilitate connections with the experiments in the main area
- **Re-evaluation of** current and LIU-compatible beam parameters is being prepared, that will lead to a compatibility evaluation and strategy formulation for a beam dump upgrade.
- **A new maximum of 2 x 10^{16} protons/year** is OK for Radiation Protection (previous limit: 10^{16} p/y).
  - Enables the accomodation of ~double number of experiments/year, or allow higher intensities / experiment





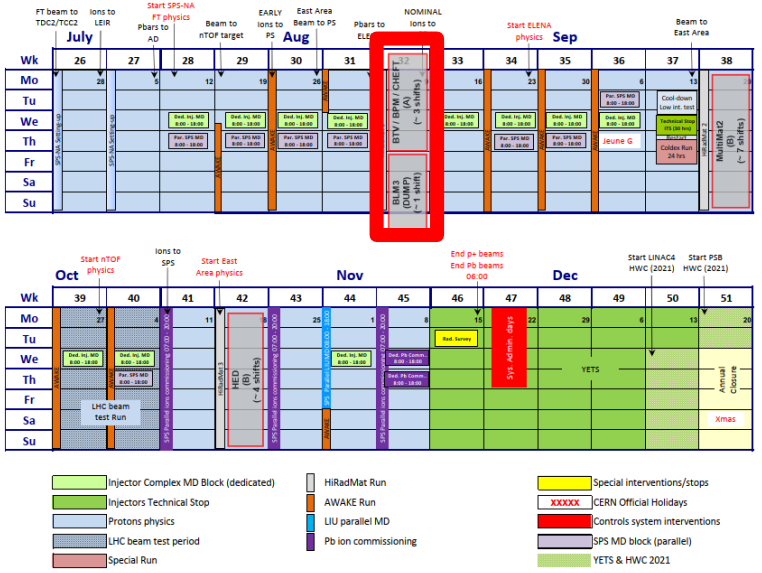
Approved Experiments for 2021

Identifier	Experiment Name	Scientific Board Status	IEFC approval	Final Technical Board Date	Beam Time Week (tentative)	Cummulative Intensity Requested [p]	Maximum Pulse Intensity	TNA requested / Form Submitted
HRMT-52	BTV524	Recommended	**Approved**	**25/05/2020**	Week 32 (9^{th} – 16^{th} Aug)	**1.7×10^{15}**	**$288 \times 1.2 \times 10^{11}$**	**No TNA necessary**
HRMT-53	CHEFT	Recommended	**Approved**	**25/05/2020**	Week 32 (9^{th} – 16^{th} Aug)	**3.47×10^{15}**	**$288 \times 1.2 \times 10^{11}$**	**No TNA necessary**
HRMT-54	BPM	Recommended	**Approved**	**25/05/2020**	Week 32 (9^{th} – 16^{th} Aug)	**Parasitic with BTV524 & CHEFT**	**$288 \times 1.2 \times 10^{11}$**	**No TNA necessary**
HRMT-55	BLM3	Recommended	**Approved**	**25/05/2020**	Week 32 (9^{th} – 16^{th} Aug)	**0.9×10^{15}**	**$288 \times 1.2 \times 10^{11}$**	**Yes / Yes**
HRMT-56	HED	Recommended	**Approved**	**25/05/2020**	Week 42 (18^{th} – 24^{th} Oct)	**2.6×10^{15}**	**$288 \times 1.2 \times 10^{11}$**	**Yes / Yes**
HRMT-57	MultiMat2	Recommended	**Approved**	**25/05/2020**	Week 38 (20^{th} – 26^{th} Sept)	**2.5×10^{15}**	**$288 \times 1.2 \times 10^{11}$**	**Yes / Yes**

Total requested : 1.1×10^{16} protons – Approved by the IEFC comittee

First slot – week 32

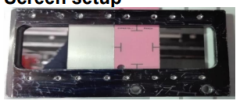
- BTV524, CHEFT (+BPM : 3 shifts) + BLM3 (1 shift)
  - **BTV524: Validation of its spatial resolution** over the full range of intensities / spot-sizes. Part of the facility's instrumentation → concludes the commissioning that started in 2018.
  - **CHEFT: Proton irradiation of Carbon Nano Tube Wires** with different beam sizes and intensities for evaluating their use in beam-instrumentation devices – robust in very high intensities.
  - **BPM: Test of high-frequency beam position monitor** for LHC.
  - **BLM3: Functionality, Stability, Calibration and Saturation of different beam loss monitors**, for ESS, GSI-FAIR and CERN.



Proposal for 2021 : Phase 2 **Courtesy: T. Lefevre**

- **Remaining test:**
  - 0.5mm and 0.25mm beam size intensity scan → ~1E15p

Screen setup



SiC 0.5mm | Ti 0.1mm | Chromox 0.4mm | Sigradur G Glassy C 0.5mm

- **New Basler digital camera**
  - Tested in parallel last run
  - Improved resolution
    - 1920x1200 pixels
    - 50um pixel size
- **New linear motorized stage with 10 OD filters to cover dynamic range**

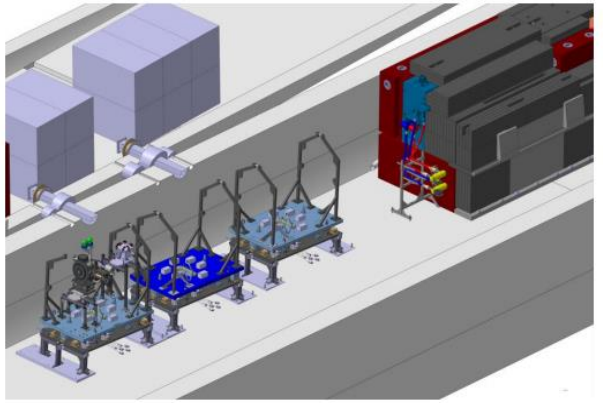
Risks Mitigation

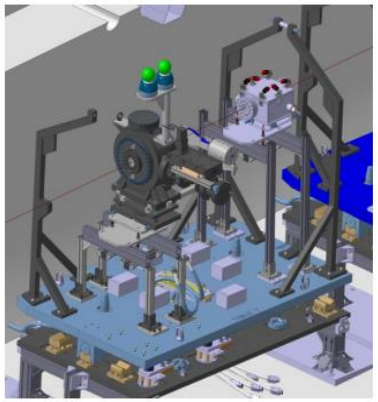
The screens are in an independent vacuum vessel
- Worse case is the breaking of a screen (cracks)
- No contamination risk
- Would go to CERN irradiated trash
- Easy to replace

Total protons requested: 6.1 x 10^{15}

HRMT53-CHEFT

Integration in Table A

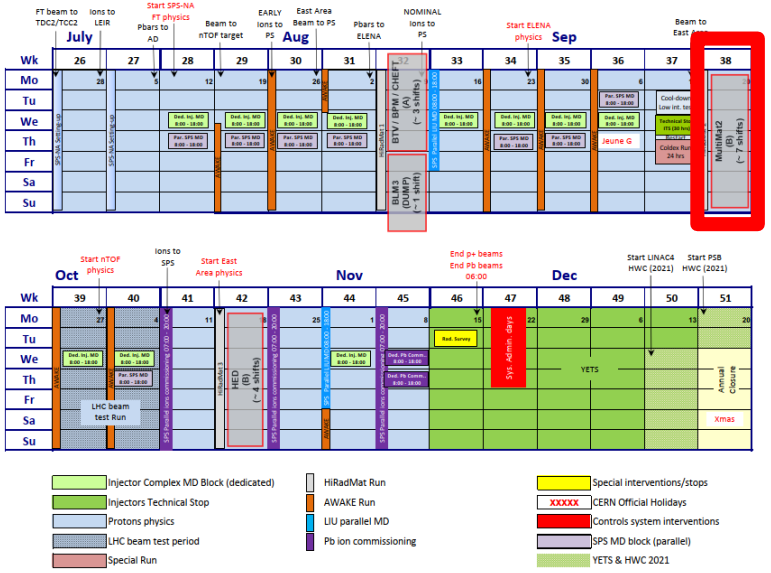


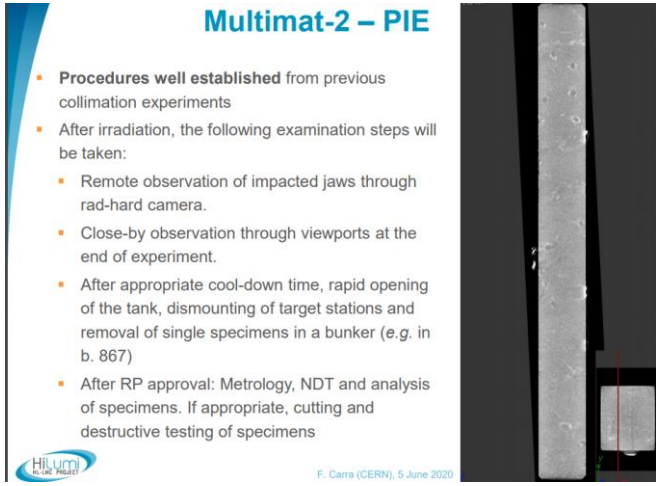


Courtesy: T. Lefevre

Second slot – week 38

- Multimat2 (7 shifts)
  - **Collimator and BID interesting material impact tests** with beam pulses up to the maximum pulse intensity (288 bunches @ 1.2 x10^{11} ppb)
  - **Collaborators** from CERN, Univ. Malta, and Politecnico di Milano
  - **Follow up of previous experiments** towards the deep understanding of key materials for accelerator applications – focused on industrial grades for HL-LHC collimators.



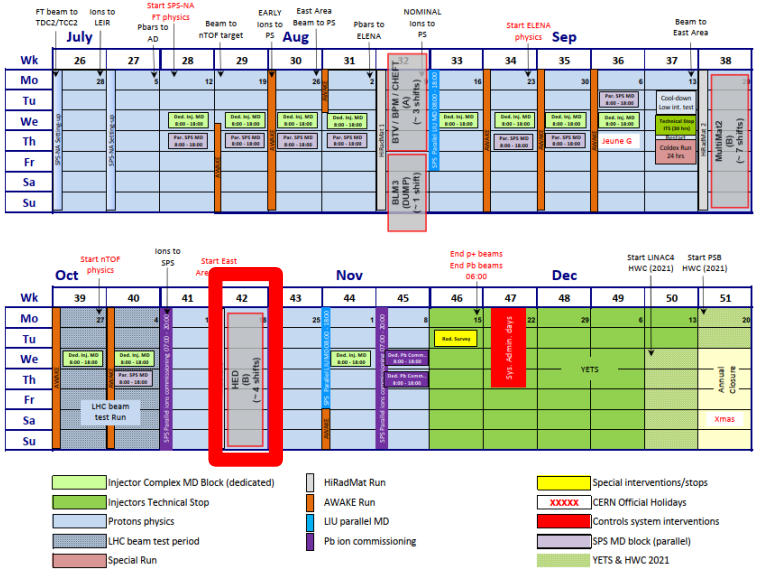


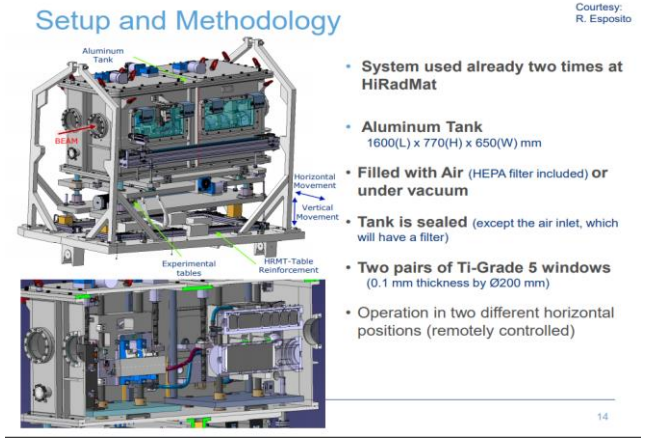
Courtesy: F. Carra

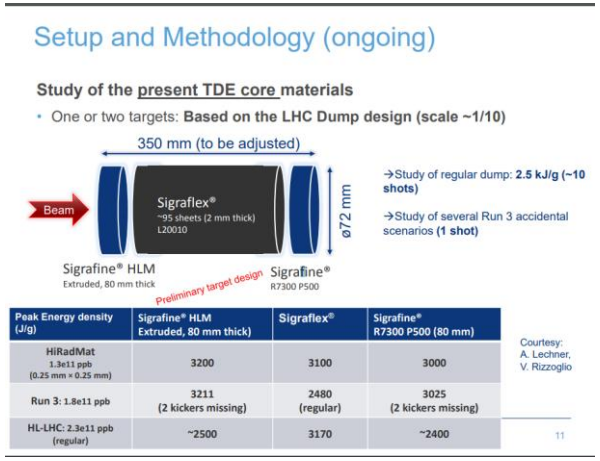
Total protons requested: 2.5 x 10^{15}

Third slot – week 42

- HED (4 shifts)
  - **Probing the robustness of low-density carbon-based materials,** key candidates for the design of the HL-LHC external beam dump core (TDE).
  - **New Collaborators** from NTNU and SINTEF
  - **Results very important for present and future beam dumps** (present LHC dump, future HL-LHC, FCC-e diluter..).







Courtesy: F.X Nuiry, M. Calviani

Total protons requested: 2.6 x 10^{15}

ARIES TNA Approved Requests & AU until April'22

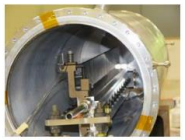
Identifier	Experiment Name	Scientific Board Status	IEFC approval	Final Technical Board Date	Access Units	Persons	Approved by the USP
HRMT-55	BLM3	Recommended	Approved	25/05/2020	440	3	Yes
HRMT-56	HED	Recommended	Approved	25/05/2020	288	5	
HRMT-57	MultiMat2	Recommended	Approved	25/05/2020	80	1	
HRMT-58	RADIATE	Recommended	No	TBD	216	5	
M49 – M60 (until April '22)					1024	14 (6 new)	
M1-M48 (since the begginging of ARIES)					1656	39	
Foreseen for project (M1-M48)					200	20	

- The above are the recently approved experiments that will take place during the 1-year extension of ARIES (M49 – M60)
- 50 % TNA support for third year on the overall number of experiments.

Future experiments 2022++

Motivation

- Material tests to guide the design and reliable operation of beam-intercepting devices in future high intensity multi-MW accelerator facilities (eg. LBNF, Hyper-K, HL-LHC, MLF)
- Understand the dynamic material limits under highly localized strain rates and temperatures to avoid compromising particle production efficiency of targets by limiting beam parameters
- Continue to explore and evaluate novel materials for future target systems and beam-intercepting devices



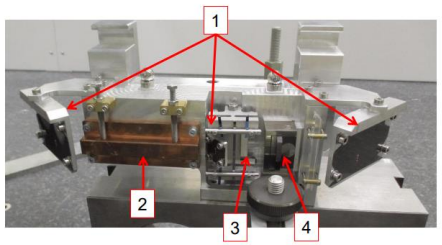
NOvA graphite target, FNAL

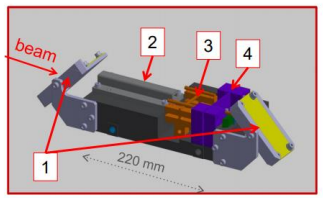
T2K target Ti window, J-PARC

R a D I A T E Collaboration

Radiation Damage In Accelerator Target Environments

Target assembly

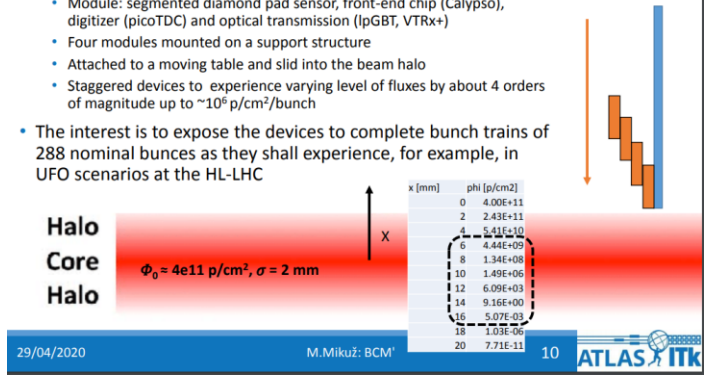




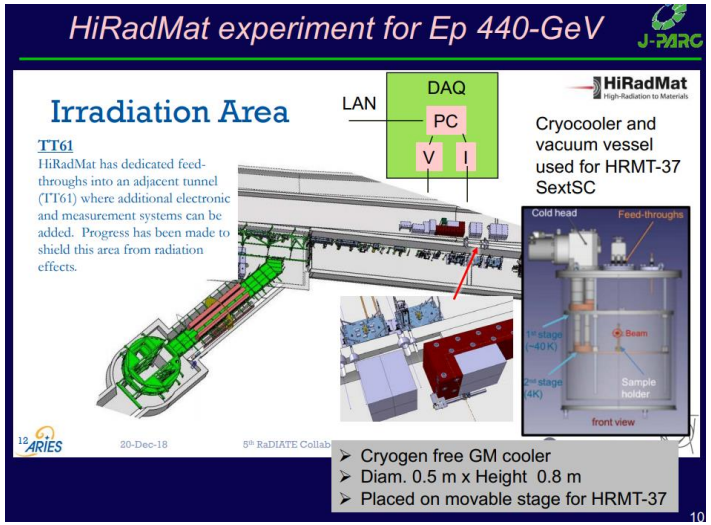
The HiRadMat crystal experiment target assembly:
(1) are the three Gafchromic foils
(2) is the copper mask for (H & V) alignment using a BLM (not shown)
(3) and (4) crystals, pre-aligned with respect to the mask

BCM' @ HiRadMat – Measurement Methods

- The test will comprise two modules of each flavour (*lumi/abort*)
  - Module: segmented diamond pad sensor, front-end chip (Calypso), digitizer (picoTDC) and optical transmission (lpGBT, VTRx+)
  - Four modules mounted on a support structure
  - Attached to a moving table and slid into the beam halo
  - Staggered devices to experience varying level of fluxes by about 4 orders of magnitude up to ~10^6 p/cm²/bunch
- The interest is to expose the devices to complete bunch trains of 288 nominal bunces as they shall experience, for example, in UFO scenarios at the HL-LHC



HiRadMat experiment for Ep 440-GeV



Generating ultra-dense pair beams using 400 GeV/c protons

C. D. Arrowsmith[1], N. Shukla[2], N. Charitonidis[3], R. Boni[4], H. Chen[5], T. Davenne[6], D. H. Froula[4], B. T. Huffman[1], Y. Kadi[3], B. Reville[7], S. Richardson[8], S. Sarkar[1], J. L. Shaw[4], L. O. Silva[2], R. M. G. M. Trines[6], R. Bingham[6,9], G. Gregori[1]

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[2]*GoLP/Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade de Lisboa, 1049-001 Lisboa, Portugal*
[3]*European Organization for Nuclear Research (CERN), CH-1211 Geneva 23, Switzerland*
[4]*University of Rochester Laboratory for Laser Energetics, Rochester NY 14623, USA*
[5]*Lawrence Livermore National Laboratory, 7000 East Ave, Livermore, California 94550, USA*
[6]*Rutherford Appleton Laboratory, Chilton, Didcot OX11 0QX, UK*
[7]*Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany*
[8]*Atomic Weapons Establishment, Aldermaston, Reading, Berkshire RG7 4PR, UK*
[9]*Department of Physics, University of Strathclyde, Glasgow G4 0NG, UK*

(Dated: November 10, 2020)

A previously unexplored experimental scheme is presented for generating low-divergence, ultra-dense, relativistic, electron-positron beams using 400 GeV/c protons available at facilities such as HiRadMat and AWAKE at CERN. Preliminary Monte-Carlo and Particle-in-cell simulations demonstrate the possibility of generating beams containing $10^{13}-10^{14}$ electron-positron pairs at sufficiently high densities to drive collisionless beam-plasma instabilities, which are expected to play an important role in magnetic field generation and the related radiation signatures of relativistic astrophysical phenomena. The pair beams are quasi-neutral, with size exceeding several skin-depths in all dimensions, allowing for the first time the examination of the effect of competition between transverse and longitudinal instability modes on the growth of magnetic fields. Furthermore, the presented scheme allows for the possibility of controlling the relative density of hadrons to electron-positron pairs in the beam, making it possible to explore the parameter spaces for different astrophysical environments.

An outlook in the future

Identifier	Experiment Name	Scientific Board Status	First Technical Board Status	IEFC Approval	Final Technical Board Date	Beam Time Week (tentative)	Experiment Documentation EDMS #	Cummulative Intensity Requested [p]
p-2001-4	ScintOF	Q2/Q3 (2021)	Q3/Q4 (2021)	Q4 (2021)	Q1 (2022)	?	2421040	10^{15}
p-2003	CRY3	Conditionally Recommended	Q3/Q4 (2021)	Q4 (2021)	Q1 (2022)	2022	2421042	$5x10^{14}$
p-2004	RaDIATE2022	Recommended	Q3/Q4 (2021)	Q4 (2021)	Q1 (2022)	2022	2421043	$3x10^{14}$
p-2005	DPA	Recommended	Q3/Q4 (2021)	Q4 (2021)	Q1 (2022)	2022	2421044	10^{15}
p-2006	ATLAS-ITk	Recommended	Q3/Q4 (2021)	Q4 (2021)	Q1 (2022)	2022	2421045	10^{14}
p-2009	SCcoils	Q2/Q3 (2021)	Q3/Q4 (2021)	Q4 (2021)	Q1 (2022)	2022	2421051	$6x10^{14}$
HRMT-25	TPSG4-2	Recommended	Q3/Q4 (2021)	tbd	tbd	2023 ?	2421049	$3x10^{14}$ (LIU)
LOIs (Oxford, HED-2, HL-LHC collimator ….)	…	..	..	..	..	..	..	..

2022	AU
HRMT58: RaDIATE2022	728
p-2005 DPA	tbs
p-2009 SCcoils	tbs
LoI, Oxford	tbs
EoI, HED-2	tbs

HiRadMat facility strongly looking forward for the successor of ARIES – Absolutely critical in order to support the experimental efforts that are already preparing their beam time in the facility.

Potential new targets for TNA (2022-2024) : ~**3000 Access Units (h)**

GSI/M-Branch Facility

- **All on track**
- **3 projects are scheduled for the actual run:**
  - one group will travel to GSI
  - the other two groups will handle the experiment remote-controlled with assistance of the local group.

Achieved Transnational Access Units @ M46 (February 2021):

GSI/M-branch	User-projects			Users supported	Units of access (1h)
	Submitted	Selected	Supported		
Year 1 + 2 (M1-M48)	4	4	4	33 (12*)	512
Scheduled for run 2021 (March-June)	Continuation of 3 projects			29** (2*)	312
Foreseen for project (M1-M48)	8			48	480 → 768 h

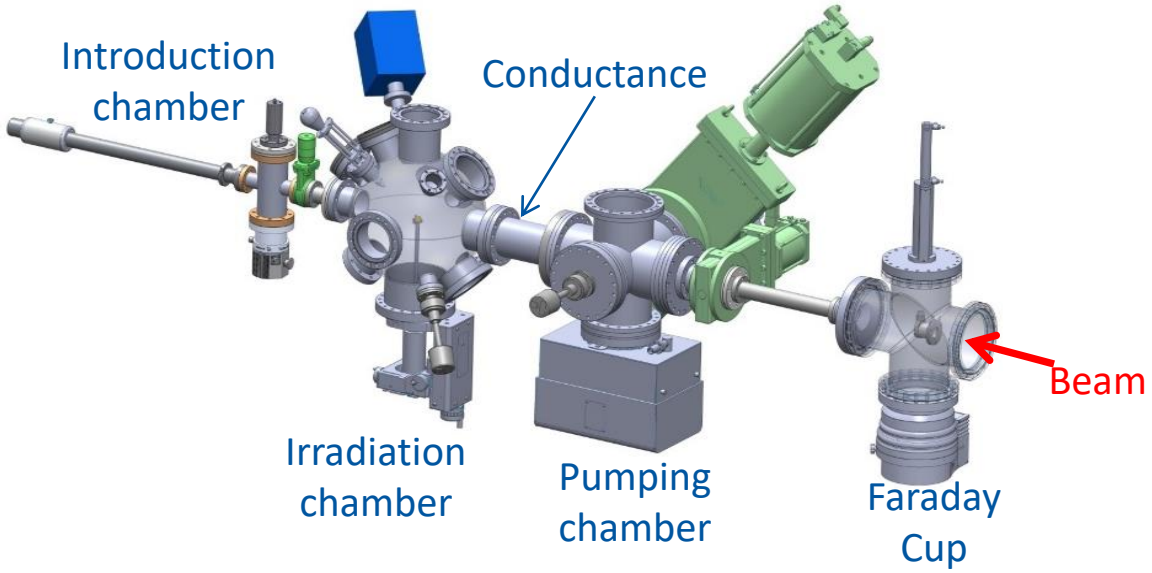
* With financial support

** due to COVID-19, 2 projects run with full remote-control

Desorption yield measurements

UMat_Steydli: "Ion-induced desorption for accelerator vacuum"

- Context : the outgassing due to ion induced desorption can be a severe limitation in modern accelerator developments
- Goal : find the best surface treatment of Cu, W and Stainless Steel samples in order to limit the released gas after impact
- Setup : M-Branch, UNILAC, GSI Darmstadt
- Ion Beam : Ca19+ or Ca10+ at 4.8 MeV/u, 5 Hz pulsed beam, pulse length = 5 ms



Interaction chamber :

- **Calibrated** Residual Gas Analyzer (RGA) in order to determine **the nature of released gas**
- Bayard Alpert gauge measures the **total pressure**
- Base pressure : 10^{-9} mbar
- Samples

Pumping chamber :

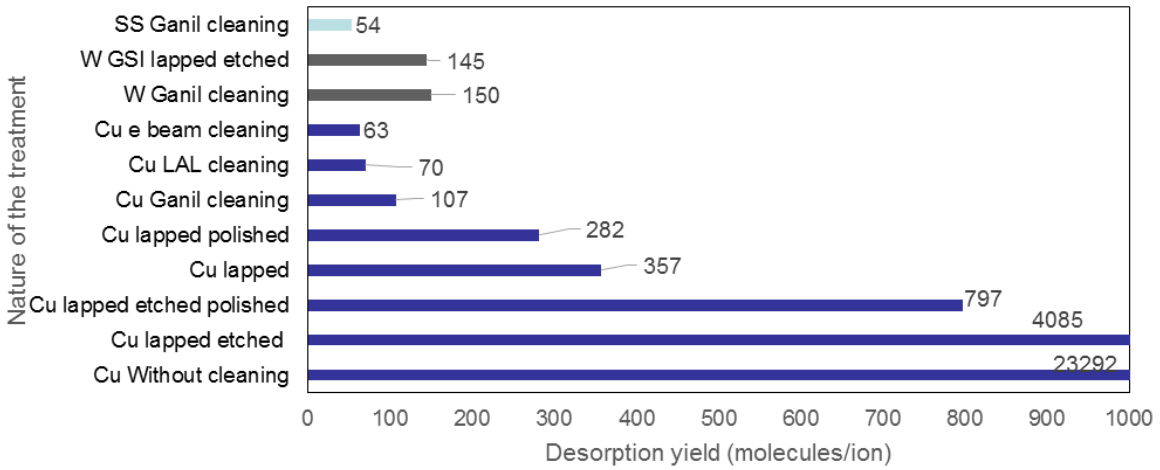
- Ionic pump
- Bayard Alpert gauge
- Turbomolecular pump

Desorption yield measurements

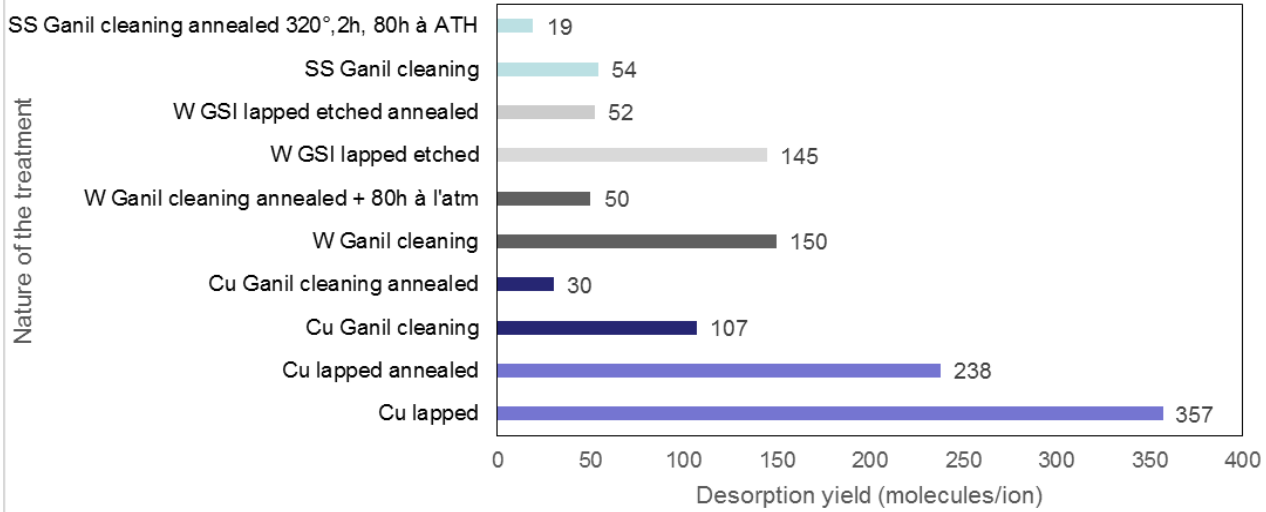
UMat_Steydli: "Ion-induced desorption for accelerator vacuum"

→ Preparation of the surface has a large effect on the desorption yield η
- e-beam cleaning is very interesting for Cu
- Annealing of the surface (if possible) improves η

➢ Influence of the cleaning procedure



➢ Influence of the thermal treatment



Next steps : - long irradiation to show the surface cleaning by the beam (scrubbing effect)
- determine the desorption yield η with partial pressure of released gases

Conclusions

- HiRadMat **is ready to startup** in summer 2021 with 3 approved slots for 2021 (6 experiments)
  - Outlook for 2022-2024 ~3000 AU expected for TNA.

- **Two publications (MultiMat experiment) since the last report :**
  - M. Portelli et al, https://doi.org/10.1155/2021/8879400
  - F. Carra et al, https://doi.org/10.1155/2021/8855582

- GSI/M-branch Facility is actually running (**312h are scheduled for ARIES TNA in 2021**), total allocated access of 768h will be served by June 2021
- Further beamtime is foreseen for 2022 (draft schedule available)
  - Outlook: Stable conditions for the coming 5 years – TNA expected ~1000 AU for the next 4-years.


CERN